5 Observing with SIRTF

The SIRTF observer's interface to the Observatory, including the instruments, is the set of seven Astronomical Observation Templates or AOTs. SIRTF's science instruments are relatively simple in the sense of having few modes and even fewer moving parts (only two -- the IRAC shutter and the MIPS scan mirror). AOTs are a central design concept in SIRTF's science operations. The use of relatively simple parameterized observing modes will enhance the reliability of SIRTF observations and calibration, improve the archival value of SIRTF data and reduce cost.

This chapter describes the SIRTF AOTs, introduces the concept of an Astronomical Observation Request (AOR), introduces the SSC-provided tools for planning and creating observations and describes some of the policies and procedures related to observing with SIRTF. Special types of observations, such as Solar System Objects (SSOs), Targets of Opportunity and Generic Target observations are also discussed.

The tool which SIRTF observers will use most often is the SIRTF Planning Observations Tool (SPOT), which is described in Section 5.3.

5.1 The Seven SIRTF Astronomical Observation Templates -- AOTs

An AOT is a distinct SIRTF observing mode; there are seven SIRTF AOTs for the three science instruments. Four of the AOTs are available at the time SIRTF is launched; these are known as the first generation AOTs. The remaining three will become available at the time of the second General Observer *Call for Proposals* and are known as second generation AOTs. For information on proposing to use second generation AOTs for Legacy Science, please see the *SIRTF Legacy Science Call for Proposals(*Section 3.4).

The observing modes are:

- **InfraRed Array Camera (IRAC) Mapping/Photometry**

  The IRAC AOT is used for simultaneous imaging at 3.6, 4.5, 5.8 and 8.0 microns, over the two 5.12 by 5.12 arcminute fields of view.

- **InfraRed Spectrograph (IRS) Staring-Mode Spectroscopy**

  The IRS staring mode is used for low-resolution long-slit spectroscopy (R= 62-124) from 5.3 to 40 microns and high-resolution spectroscopy (R=600) from 10 to 37 microns. It also returns images from the IRS peak-up array, which has a field-of-view of approximately 1 arcminute square and two filters covering 13.5-18.5 microns and 18.5-26 microns. The IRS Staring mode also supports step-and-stare raster mapping.

- **Multiband Imaging Photometer for SIRTF (MIPS) Photometry and Super Resolution Imaging**

  The MIPS Photometry and Super Resolution AOT is used for imaging photometry and high resolution imaging at 24, 70 and 160 microns.

- **MIPS Freeze-Frame Scan Mapping**

  The MIPS Scan Map AOT is used for large field maps at 24, 70 and 160 microns. The maps are constructed using slow telescope scanning, combined with motion compensation using a cryogenic scan mirror. Maps are built up of 5.1 arcminute wide strips between 0.5 and 6 degrees in length.

- **IRS Spectral Mapping (Second Generation)**

  The IRS Spectral Mapping AOT will be used to perform slit scanning spectroscopy for fields up to a few arcminutes in extent.

- **MIPS Total Power Measurement (Second Generation)**

  The MIPS Total Power Mode AOT will provide zero-level-reference observations for absolute brightness of extended sources.

- **MIPS Spectral Energy Distribution (Second Generation)**

  The MIPS Spectral Energy Distribution AOT will be used for very low resolution (R=15-25) spectroscopy covering 55-96 microns using the MIPS 70 micron Ge:Ga array.

Each AOT and its usage are discussed in detail within the respective Instrument-specific chapter. Cookbook examples of how to create observations using the AOTs are also included in the Instrument-specific chapters 6 through 8.

5.2 Astronomical Observation Request -- AOR

The fundamental unit of SIRTF observing is the Astronomical Observation Request, or AOR. When all the relevant parameters for an AOT are specified and linked to a description of the target, the resulting fully specified observation is called an AOR. AORs are normally created by using SPOT (see Section 5.3). An AOR can be thought of as list of parameters that, when properly interpreted, completely describe an observation. In fact, an AOR is represented in the SIRTF Science Operations Database (SODB) in an ASCII *keyword = value* format which is used to generate the list of commands that are sent to the Observatory to carry out the observation. This ASCII format is what SPOT actually creates and stores in its output file. This file of ASCII AORs (the ".aor" file) is what proposers must submit as part of their SIRTF proposal. The parameters of the AOT are specified in SPOT by filling out a form sometimes called an "AOT Front End."

The AOR is the fundamental scheduling unit for SIRTF; an AOR cannot be subdivided, will not be interrupted for other activities (such as Downlinks) and will be handled as a unit by the Observatory. Because of this non-interruptible nature and the need to perform certain activities periodically (e.g., detector anneals, pointing system calibrations and Downlinks) there is a maximum duration for an AOR. Based on current knowledge, that maximum time is 3 hours for MIPS AORs and 6 hours for IRAC and IRS AORs. Longer observations can be specified using relational constraints to identify the AORs as members of a related group (see Section 5.5.3).

An AOR contains three categories of information:

- **Astronomical Target**

  The "target" of an AOR can be a single pointing or a cluster of pointings within a 1°radius, at which the specified observation is repeated identically. The single pointing or cluster may be either of an inertial target or a moving target.

- **Timing and Relational Constraints**

  These represent scheduling directives for an AOR or for a related group of AORs. The details of the kind of constraints that are supported are in Section 5.5.3. Timing constraints are used to specify **when** an AOR can be executed (e.g., to observe a comet at maximum solar elongation). Relational constraints are used to specify **how** AORs within a group are **related to one another** (e.g., a series of AORs that define a very deep map and must be executed consecutively).

- **AOT-specific parameters**

  As the name implies, these vary from AOT to AOT. They include instrument configuration, exposure time and dedicated mapping parameters.

5.3 Science User Tools

Science User Tools are software packages and other materials (such as tables and graphs) that are provided by SSC to help the astronomical community plan, prepare, submit, monitor and interpret the results of their SIRTF observations.

5.3.1 SIRTF Planning Observations Tool -- SPOT

The SIRTF Planning Observations Tool (SPOT) is a JAVA-based software tool intended to assist potential and approved SIRTF observers in planning and modifying their observations. SPOT, along with the *SPOT User's Guide*, can be downloaded from the Proposal Kit section of the SIRTF Science Center Web pages (http://sirtf.caltech.edu/). The core of the package is a GUI-driven observation-planning program that allows users to specify targets, exposure times, instrument modes, and observing constraints. It provides total spacecraft time (including Observatory overheads) for the requested observations along with target visibility information, focal plane position angle for a selected observation date, and estimates of the zodiacal and cosmic infrared background at the target. When proposing SIRTF observations, SPOT creates a text file (".aor" file) with details of the observations, which is submitted as part of the proposal. In the future, SPOT may use a client-server system to communicate with the SIRTF Science Operations Database (SODB) to support "check-out" of active SIRTF programs for approved modifications (see Section 5.4).

SPOT is currently supported on Windows (95, 98, NT), Linux, and Sun Solaris (2.6, 2.7) platforms. For more details see the *SPOT User’s Guide* and *Release Notes*, available at the Web site with the software. A network connection to the SIRTF Science Center is required to obtain observing time estimates, visibility, orientation, or background estimate information.

SPOT does not currently have integrated visualization capabilities for displaying images of the sky overlaid with the SIRTF focal plane or coverage maps for a specified observation. The stand-alone tool IRSky is now available for visualization.

5.3.2 IRSky

IRSky is an X-Windows based package available through telnet access to *irsky.ipac.caltech.edu*, userid: *irsky*, no password (or the observer can access it from the IPAC homepage or through the Proposal Kit Web pages). With IRSky the observer can overlay the SIRTF focal plane on IRAS Sky Survey Atlas (ISSA) 12, 25, 60, and 100 micron maps of the sky to help visualize specific SIRTF observations. It does not provide overlays of coverage maps for SIRTF. IRSky will allow the observer to input a position angle, which can be obtained for a particular target and date in SPOT, to indicate how the SIRTF focal plane will appear on the sky for specific observations. An X-Windows emulator is required to use IRSky from a PC.

Note that IRSky estimates the background emission using a different model than is used by SPOT. The IRSky background estimator uses a zodiacal background model and an interstellar cirrus background estimator derived from IRAS data. The model incorporated into SPOT is based on both IRAS and COBE data, can take into account the time of observation in calculating the zodiacal light background component, and uses improved wavelength-interpolation schemes. However, near the Galactic plane or other very bright extended emission, the IRSky estimator is expected to give better results than the background model in SPOT.

The SIRTF background estimator used in SPOT is documented in a memo, which is available from the SSC WWW Site.

5.4 Modification of Observing Programs

Due to the simplicity of the constraints imposed upon SIRTF observations, the SIRTF Science Center envisions that it will be able to execute most observations exactly as they are specified in response to the *Call for Proposals*. Therefore, SIRTF will expect General Observers to provide sufficient information at the time of proposal submission to implement the observations (i.e. completed AORs). The process is somewhat different for Legacy Science Proposers, who need only submit a representative sample of completed AORs (see Section 6.1.3 of CP).

Observers will be given the option of modifying their approved AORs prior to making them available for scheduling (see *SIRTF Observing Policy #4* for details). In addition, in case of conflicts or special needs, it will be possible for observers to request a password-access to modify their (not yet scheduled) AORs via the SIRTF HelpDesk. The request must be accompanied by a strong justification for the proposed changes and cannot be made during any blackout period (see the SIRTF WWW pages for a schedule of blackout periods). However an observer can at any time request (again with strong justification) that a scheduling "hold" be placed on observations which are not feasible. Only certain types of modifications are permitted, and the observer is responsible for knowing the policies prior to requesting checkout of his or her observing program.

Upon completion of approved modifications, the observer will need to resubmit the revised program and SSC will review the changes and re-check for duplications prior to re-releasing the AORs for scheduling. Once a program has been resubmitted, the access for modifications will be disabled and any further modification will require a new request for access with supporting justification.

5.5 Scheduling Considerations

The technical issues of telecommunications and Observatory performance that drive science instrument campaign planning and the basic scheduling time-scales are addressed in Chapter 3. In this section, the planned scheduling process is addressed from the observer's point of view.

The use of scheduling constraints is also discussed. Scheduling constraints restrict the ability of the planning and scheduling system to create efficient schedules and to ensure the feasibility of scheduling all AORs. Therefore a scientific justification is required for the use of scheduling constraints.

5.5.1 Scheduling Methodology

The SIRTF scheduling process will construct short-term observing schedules of one-week lengths. Scheduling is done one week at a time regardless of the Instrument Campaign schedule, and a one-week schedule will generally contain observations using more than one science instrument. The one-week schedule loads will be uplinked weekly, following final internal review and approval. After a schedule has been uplinked, it will not normally be altered except in unusual circumstances (e.g., activation of Target of Opportunity programs). Due to the fact that SIRTF is in contact with the ground for only a brief period every 12-24 hours, it is not practical to make changes to the on-board schedule on very short time-scales; the fastest a ToO can be accommodated is within 48 hours.

Observations will be grouped into Instrument Campaigns, which are periods of several days during which only one instrument is used. Instrument Campaigns will vary in length as needed to accommodate the science program, but it is expected that typically they will last 3 to 10 days.

Policies regarding interruption of Instrument Campaigns and schedule changes on short notice are discussed in more detail in the *SIRTF Observing Policies*. Observers should also consult the *Observing Policies* and the SIRTF Web Site for information on proposing programs seeking frequent instrument changeovers as scheduling such programs is difficult and reduces Observatory efficiency. Observers considering such programs should also be aware of hardware-related performance issues pertaining to instrument changeovers (see Chapter 3).

The planning and scheduling process includes determining the optimum structure of Instrument Campaigns. This type of campaign planning will occur shortly after a new set of observations becomes available during each proposal Cycle. This Baseline Instrument Campaign will be published on the WWW once it is considered stable, but it is subject to change without notice due to the need to respond to actual events on-orbit.

5.5.2 Notification that an AOR has been Scheduled

Just before a schedule has been uplinked to the spacecraft, the list of scheduled AORs and their nominal execution times will be published on the SIRTF WWW site. Unless an absolute scheduling time has been specified at the time of scheduling (as is always the case for moving targets), the actual execution time of an AOR may differ from the scheduled time by a small amount (possibly up to several minutes). This is due to the non-deterministic nature of the on-board indicators for slew completion and settle time.

The appearance of a particular AOR in the published schedule will be the only notification to observers that the AOR has been officially scheduled. *Thus observers will normally receive at most a one-week advance notice that their AOR has been scheduled at a specific time.* Once an AOR has been scheduled only a significant anomaly or a rapid-turnaround ToO could cause the schedule to change.

In the case of AORs that are highly time-constrained for science reasons, if a specific sequence or dates have been provided to the Observatory in advance, the Planning & Scheduling Team will make every effort to schedule those AORs accordingly. This information should be provided at the time of proposal submission, if possible, and always requires a scientific justification. A SIRTF observer may assume that any specific dates and times requested in an approved proposal will be accommodated, unless otherwise notified by the SSC. In the event of a serious conflict, the SSC will contact the affected observer(s) as soon as possible to resolve the problem. However, even for heavily constrained AORs, the only *formal* announcement of their place in the SIRTF schedule will be their appearance in the latest online weekly schedule.

5.5.3 Requesting Scheduling Constraints for Science Reasons

The scheduling software will be able to handle common types of constraints and logical linkages, such as those needed for periodic monitoring of a target. However, because scheduling constraints restrict the ability of the scheduling system to produce efficient schedules and may render scheduling some observations infeasible, the usage of any type of timing or relational constraint **requires a scientific justification.** The justification must be provided at the time of proposal submission (or modification if the constraint has been subsequently added).

5.5.3.1 RECOMMENDATIONS FOR THE USE OF SCHEDULING CONSTRAINTS

If a scheduling constraint is required, it is **strongly recommended that the minimum constraint necessary** to preserve the scientific goal of the observation(s) be applied. In general, larger time windows are preferred and loose groupings are preferred to non-interruptible sequences of observations. For very long observations, strategies which permit independent scheduling of the component AORs are much preferred; this not only enhances scheduling efficiency, but also makes the observation as a whole much more robust against the failure of component AORs. As a general rule of thumb, groups of constrained AORs that occupy more than about 75% of the time period during which they can be scheduled will have a strong negative impact on efficiency and may not be feasible to schedule. For example, 40 hours of observations that must be done within a 40-hour period cannot be scheduled, whereas the same 40 hours of AORs may be quite feasible if they can be scheduled anytime within the same one-week period.

When designing scheduling constraints, the observer must take into account the natural 12 to 24-hour time scale for Periods of Autonomous Operation (PAOs) and that Instrument campaigns will normally be 3 to 10 days. In addition, instrument and PCS calibration and instrument and spacecraft maintenance activities can take 10% or more of the available time during a given PAO. Based upon current plans, about 9.5 hours out of each 12 hour PAO will be available for IRAC or IRS observations and about 11 out of a typical 12 hour PAO for MIPS. Some PAOs, e.g. at the beginning and end of a campaign, may contain a higher fraction of calibration and maintenance activities. Note that during the early part of the mission, shorter PAOs and shorter campaigns will likely be the rule.

5.5.3.2 Specification of Scheduling Constraints

Scheduling constraints are specified at the time the AORs are completed, using the constraint-editing capabilities of SPOT. Please see the *SPOT User's Guide* for details on how to specify constraints.

The following types of scheduling constraints are supported for both inertial and moving targets:

- **Timing Constraints**

  Timing constraints consist of defining a window or series of windows for the start time of an AOR. If the open and close time of the window are specified to be identical, then the AOR will be scheduled as an absolute time observation at that time, and will be executed at that time or no more than 2 seconds later.

- **Relational Constraints**

  Relational constraints are ordering or grouping constraints that are applied to a group of AORs. There are four basic types of relational constraint supported by SIRTF.

  - **Ordered Non-interruptible Group = Chain**

    A chain can be thought of as a list of AORs that must be executed consecutively in the order specified and without any kind of activity intervening. Note that the total time for the entire ordered non-interruptible group can not exceed the maximum time for an individual AOR; for longer observing sequences, an interruptible group must be used. This type of constraint might be used for an on/off pair of observations.

  - **Ordered Interruptible Group = Sequence**

    A sequence can be thought of as a list of AORs that must be executed consecutively in the order specified, but specific types of activities such as necessary calibrations, Downlinks, etc. may intervene. This type of constraint might be used for a deep mapping sequence where the order of coverage is considered important.

  - **Group-within**

    A group-within is similar to an ordered interruptible group but the list might be executed in any order during a time period of specified length.

♦ **Follow-on**

This type of constraint can be thought of as a statement that *Follow-On-AOR* must be scheduled within *Time-Window* following *Precursor-AOR*. The follow-on constraint is used to prevent early execution of an observation when the success or content of the follow-on is dependent upon the successful execution of a precursor observation. An example would be a lengthy IRS observation where the suitability of the peak-up target cannot be verified at the time of planning. In that case a test peak-up AOR would be made as a precursor to the deep spectrum. One AOR may serve as the precursor to more than one follow-on, but a follow-on may have only one precursor.

- **Timing and Relational Constraints can be combined**

  For example, a series of AORs used to take spectra of a comet over a long track which needed to be broken up into segments due to curvature, might be constrained as a chain with an associated timing constraint related to the acceptable range of solar elongations.

5.6 Solar System Objects

SIRTF will support observations of Solar System Objects (SSOs), tracking in linear segments at rates up to 1"/s as described in Chapter 3. All instruments and all observing modes can be used while tracking. For IRS, peak-ups are currently restricted to be performed only on the spectrometry target or a point source that is co-moving with it.

5.6.1 Tracking Performance

SIRTF's SSO tracking capability is similar to its scanning capability and the performance is described in Section 3.4.4.

One consequence for the SSO observer is that observations of sources that have significant curvature during the time of an AOR when projected onto an equatorial map may need to be broken up into a series of short AORs. The spacecraft does not carry any target ephemerides on board, so the track is defined at the time of scheduling and formulated as a vector rate in an equatorial frame. A start time and equatorial J2000 start point and time are also provided for use by the Pointing Control System (PCS). Once the track command has been issued, the onboard system will maintain knowledge of where the Observatory should be at what time, and will "catch up" with the specified track and maintain it.

5.6.2 Ephemeris Management

SIRTF uses a database of ephemerides for known Solar System Objects derived from the Horizons database maintained by the Solar System Dynamics group at the Jet Propulsion Laboratory. For proposal planning purposes, SSC will provide a core subset of ephemerides from the Horizon's database. These ephemerides are currently used to calculate visibility windows for Solar System objects through the SPOT. The core subset, listed in the Proposal Kit Web pages, will include the major planets and their satellites, the periodic comets, Kuiper Belt Objects, and a subset of the asteroid population. In order to propose for an object that is not in our SSC subset, the observer will need to contact SSC via the SIRTF Helpdesk (sirtf@ipac.caltech.edu). If the object is a known object with a NAIF ID, SSC will incorporate the object into the core database within 3 working days. If the object is newly discovered and does not yet have a NAIF ID, the observer will be able to specify the orbital elements and an ephemeris will be generated for planning purposes.

The core set of ephemerides will be updated prior to each *Call for Proposals*. In addition, whenever an SSO is scheduled (2-3 weeks prior to execution) its ephemeris will be updated as needed.

Note that observations which require ephemeris updates <2 weeks prior to execution significantly perturb the scheduling process and must be identified at the time of proposal. Late ephemeris updates are considered equivalent to medium or high-impact ToOs, depending upon the amount of lead-time given (See *SIRTF Observing Policy #5*).

5.6.3 Target Specification and Scheduling Considerations

SSO observations will normally be performed as tracked observations with both the position and the track rate/direction computed from the orbital elements derived as discussed in the previous section. At some point in the future, it will also be possible to turn off tracking and have only the position computed, but this feature is not currently available. "Shadow" background observations, in which the track is either replayed or pre-played when the target is not there, will also be specifiable.

SSO observations can be scheduled with timing constraints that are as flexible as the science goal of the observation allows. Observers are encouraged to use fairly generous windows to allow the scheduling system to shift observations around and minimize gaps. When precise timing is required, an absolute time can be specified and the flight computer will perform the observation at that time or no more than 2 seconds later.

The scheduling constraints that are supported for both inertial targets and SSOs are described in section 5.5.3. The use of any scheduling constraint requires a scientific justification.

5.6.4 Science Instrument Issues

There are no restrictions on the usage of any of the AOTs for tracked SSO observations with the exception that, for IRS, peak-up on an inertial target for spectra of a moving target is not currently supported, as previously described.

The saturation behavior of the science instruments is discussed in its instrument-specific chapter, and the scattered light characteristics of the telescope are discussed in Chapter 4.

Please note that since SSOs tend to be near the ecliptic plane, the focal plane orientation with which they can be observed is highly restricted (see Section 3.2.5).

5.7 Targets of Opportunity

Targets of Opportunity (ToOs) are a special type of observation, usually of unexpected or unpredictable transient phenomena. They include objects that can be generically identified before the onset of such phenomena (*e.g.*, recurrent novae, and variable stars) and objects that cannot *a priori* be specifically identified (*e.g.,* newly discovered comets, novae, supernovae, and gamma-ray bursts). Requests for observations of the former should be submitted through the normal proposal process and those pertaining to the latter can be requested through Director's Discretionary Time.

By its very nature, a ToO warrants urgent consideration and attention, and unique procedures to handle such observations must therefore be accommodated within all categories of SIRTF observing programs. At the time of proposal submission, investigators are required to classify each ToO request, as high, medium or low impact based on the degree that the execution of such observation affects normal SIRTF scheduling and observing procedures. High impact ToOs are those which require observations within 1 week of activation, medium impact ToOs are those which allow for 1 to 3 weeks of lead time, and low impact ToOs are those which allow 3 or more weeks of lead time. High and medium impact ToOs incur an additional overhead for each AOR. See the *Call for Proposals* and *SIRTF Observing Policy #5* for more information.

The earliest that SIRTF can carry out ToO observations is 48 hours after an approved proposal is activated. The observer must fill out a template AOR that has as much detail as possible when submitting a ToO proposal. When the proposed phenomenon occurs, the observer must activate the proposal as described below.

Note that high-impact ToOs (those that require < 1-week turnaround) put extreme stress on the scheduling system and cannot be accommodated frequently. The SSC Director must issue final approval for any high-impact ToO observations requiring an interruption of the onboard observing schedule.

5.7.1 Activation of a ToO Proposal

For an approved ToO, the observer must electronically submit a request for AOR activation to the SSC Director via the SSC HelpDesk (*sirtf@ipac.caltech.edu*). Following the request for activation, the SSC will ascertain the feasibility of conducting the ToO observations, taking into account sky visibility and the schedule of SIRTF instrument campaigns (typically, 3-10 days in extent). The observer will also submit a revised AOR, with precise coordinates and integration time. If the observations cannot be conducted on the schedule requested by the investigator, the SSC Director will consult with the PI on the scientific utility of later observations.

5.8 Generic Targets

For information on generic targets see Observing Policy #6.

5.9 Second-Look Observations

For information on second-look observations see Observing Policy #7.